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GENETIC CONTROL OF MACULATION AND HINDWING COLOR IN *APANTESIS PHALERATA* (ARCTIIDAE)[1]

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The tiger moth *Apantesis phalerata* (Harris) is a common representative of the family Arctiidae around Gainesville, Florida. During the course of a recent investigation (Bacheler, 1972) of its biological and systematic relationship with a sibling species, *A. radians* Walker, rearing studies revealed information on the inheritance of certain pattern elements in the adult stage. The normal adult male of this species has yellow hindwings and lateral abdominal stripes, and a criss-cross pattern of cream bands across black forewings. The normal female has red hindwings and abdominal stripes, and only one cream band (with a parallel, short cream bar) on black forewings (Fig. 1). This paper reports data on the genetic control of the forewing and body maculation and on the sex-limited expression of the gene controlling hindwing coloration in *Apantesis phalerata*.

METHODS

As part of life history studies on *A. phalerata*, field-collected females were brought into the laboratory for oviposition. Resulting larval broods were reared through to adulthood on an artificial diet, modified slightly (Table I) from that used by Shorey and Hale (1965).

Among the typical offspring of a phenotypically normal female (red hindwings, full maculation) collected in March 1969 were three unusually light males (almost devoid of maculation) and several females with yellow hindwings. The exact pheno-

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typic ratio in these F_1 adults was not noted since these moths were among the first reared in connection with other studies. However, each of the light males was mated to separate sibling females having the yellow hindwings. The larvae resulting from the one successful mating were reared through to adulthood. After several additional unsuccessful F_2 crosses, the F_2 progeny were then spread, labeled, and stored for later analysis.

RESULTS

Thirty-nine males and 35 females resulted from the successful mating of one of the light F_1 males to a yellow-hindwinged female sibling. Female F_2 adults were of two patterns. The first pattern was that of a typical *phalerata* female, except the normally red secondaries and abdominal area were light yellow. All 29 females displaying this pattern were uniform in expression. In the second pattern the red areas were again replaced by yellow, but there was also a loss of black maculation, resulting in females that were nearly all yellow. The typical black marginal and submarginal spots of the secondaries were absent and the black costal margin faded slightly proximally. One female of the six showing this loss of maculation had traces of submarginal spots. Only traces of postcostal maculation remained on the primaries. The patagium was entirely yellow, one female having a trace of the typical black spot. The tegulae were likewise yellow, devoid of the usual black bands. The antennae and underside of the abdomen had a few yellow scales. Both are normally black. The black dorsal abdominal stripe was considerably reduced. The two F_2 female patterns are shown in Fig. 1a-b.

About half of the 39 males showed a pattern gradation from almost typical *phalerata* males to those almost completely devoid of maculation. The other half were normal. In the transition through the series, the yellow costal stripe and postmedian transverse, subterminal W-shaped, and submedian longitudinal bands widened and fused. The black spots of the patagium, tegulae, and dorsal abdominal stripe also were reduced through the series. Four males in this transition are shown in Fig. 1d-g.

A discontinuity was noted among males which exhibited a gradation between absent maculation and normal marking. The lighter forms of one class retained most of the dark, posterior

forewing band, some of the marginal spot enclosed by the W band and the wing margin, and a distinct dorsal abdominal stripe as in normal males. The second class of nine males, containing all light forms, lacked the forewing band and marginal spot, and the dorsal abdominal stripe was reduced. The abdominal stripe, then, easily separated all the males into two distinct classes: normal (with variable expression of wing maculation in some of those males) and light. The ventral wing surfaces also easily separated the two classes. The light class lacks the one black spot near the forewing margin, and the proximal black bar along the leading edge of the forewing is broken, not solid as in the normal class (see Fig. 2). The light F_1 male successfully mated in the laboratory belonged to the first class, with a distinct dorsal abdominal stripe and solid forewing bar.

Kimball (1965) reported an aberrant male almost devoid of maculation from Gainesville, Florida, in 1959. This specimen appears identical to several in the F_2 experimental series of males. Another light male was found in July 1968 in Gainesville. It also fits well into the series, but at a slightly different point. These two wild specimens are shown in Fig. 1h-i. A third light male was found in Bradenton, Florida, in 1970. These aberrations were the only noticeably light *phalerata* found among more than 2,000 males collected during this study.

When this rare aberration of *phalerata* is collected in the future, it is hoped that an awareness of the simple mutant character of this strain will avoid taxonomic confusion and the unnecessary naming of "forms" or "species."

GENETIC ANALYSIS

The rearing of this aberrant series shows that this light form is probably inherited in simple Mendelian fashion, though the 74 progeny of the successful cross showed a considerable range of variation in maculation expressed by the controlling genotypes. One autosomal gene appears to control maculation. A simple dominant allele at this locus causes maculation and its recessive allele in the homozygous state accounts for the rare, light forms. In males, expression of the heterozygous gentotype is variable.

The genotype of the original field-collected (dark, red hindwings) parental female was, according to this genetic hypothesis, heterozygous: *DdRr*. If it were homozygous for dark maculation, no light offspring would have resulted, and if it were homozygous recessive, its own phenotype would have been light. Likewise, if it were homozygous for red hindwings, none of the offspring would have had yellow hindwings, and if it were homozygous recessive it would have had yellow hindwings.

The light aberrant male reported by Kimball and examined by us was probably a recessive homozygote for maculation while the light males found in Gainesville and Bradenton were heterozygotes.

This genetic explanation on the inheritance of hindwing coloration and maculation does have the drawback of necessitating the capture of an apparently very rare female in nature, and further, having this female mate with a rare male. However, our two-gene explanation was the simplest and the only one which fit the classes of moths so precisely. A test cross would have made the hypothesis more convincing, but was not possible at the time. Since we are not planning future work on this problem, these partial results are published in the hope of stimulating further genetic investigations on these interesting arctiids.

Hindwing color seems to be controlled by a second gene locus. The dominant allele, responsible for red hindwings, is expressed only in the female. Male hindwings are yellow, regardless of the presence of this dominant gene. The homozygous recessive state of this gene in the female results in yellow hindwings.

In the following hypothetical analysis, *D* represents the dominant gene for expression of maculation and *d* its recessive allele. *R* designates the gene for red hindwings and *r* its recessive allele for yellow.

The male and female successfully crossed in the laboratory can each have only one genotype if one follows this hypothesis. The parental genotypes, their observed and expected offspring, and X^2 values are shown below. The observed and expected numbers for both male and female moths of the laboratory cross do not differ significantly from a 3:1 ratio.

Parents: F_1 ♂ X F_1 ♀

Ddrr (Dark partly expressed) — Ddrr (Dark; yellow hindwings)

Offspring: F_2 ♀♀

Genotype	Class	Expected ratio	No. Observed	No. Expected
DDrr or Ddrr	Dark	3	29	26.25
ddrr	Light	1	6	8.75
		Totals	35	35

$X^2 = 0.770$

F_2 ♂♂

Genotype	Class	Expected ratio	No. Observed	No. Expected
DDrr or Ddrr	Dark	3	30	29.25
ddrr	Light	1	9	9.75
		Totals	39	39

$X^2 = 0.009$

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Fig. 1.—Various forms of *Apantesis phalerata*. (a) light, homozygous female; (b) dark female (normal female); with full maculation; (c) light female with full maculation; (d) dark male with full maculation; (e) heterozygous male showing partial expression of maculation; (f,g) light, homozygous males; (h) wild male collected in Gainesville, Florida, heterozygous for maculation; (i) light, homozygous male reported by Kimball (1965).

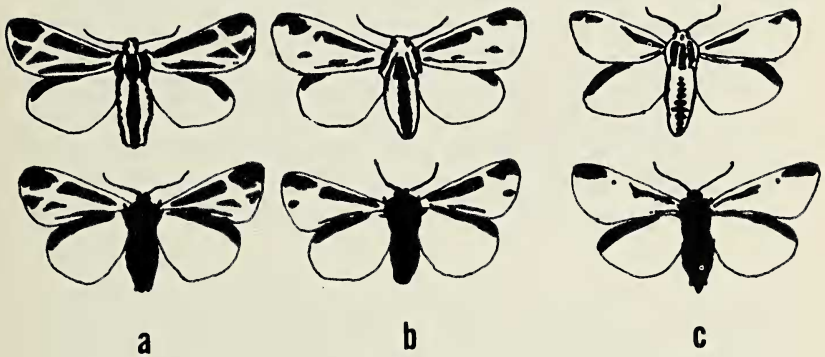

Fig. 2.—Dorsal and ventral surfaces of (a) normal homozygous males; (b) heterozygous males, and (c) light homozygous males of *Apantesis phalerata*. See text for discussion of maculation differences between the classes.

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Table 1. Modified Shorey and Hale (1965) artificial diet for rearing Apantesis phalerata.

Pinto beans (soaked overnight)	640 gm
Brewer's yeast*	100 gm
Ascorbic acid*	10 gm
Sorbic acid*	3 gm
Methyl p-hydroxybenzoate**	6 gm
Formaldehyde (37%)	6 ml
Agar*	40 gm
Water; with agar	800 ml
with dry ingredients	1000 ml

*Nutritional Biochemicals Corp., Cleveland, Oh.

**Fischer Scientific Co., Atlanta, Ga.